EQUINE EXERCISE PHYSIOLOGY 7
Equine vet. J., Suppl. **36** (2006) 98-101

Body composition in young Standardbreds in training: relationships to body condition score, physiological and locomotor variables during exercise

C. LELEU* and **C. COTREL**

Pégase Mayenne, Departement de Médecine du Sport, Centre Hospitalier, 53 015 Laval, France.

Keywords: horse; race performance; aerobic capacity; body composition; body condition score

Summary

Reasons for performing study: **Body composition is an essential factor in athletic performance of human sprinters and long distance runners. However, in horses, many questions remain concerning relationships between body composition and performance in the different equine activities.**

Objectives: **To determine relationships between body composition, body score, physiological and locomotor variables in a population of young Standardbreds in training.**

Methods: **Twenty-four 2-year-old Standardbreds were studied, body condition on a scale 0–5 and body weight recorded, and height at withers measured. Percentage of fat (%F), fat mass (FM) and fat free mass (FFM) were estimated echographically. During a standardised exercise test on the track, velocity, heart rate, respiratory frequency and blood lactate concentrations were measured. V_4 and V_{200} (velocity for a blood lactate concentration of 4 mmol/l and velocity of 200 beats/min) calculated. Basic gait variables were measured at 3 different speeds with an accelerometric device.**

Results: **Body composition variables: %F and FM were significantly related to body condition score and physiological variables. Body score was found highly correlated to %F (r = 0.64) and FM (r = 0.71). V_4 was negatively correlated to %F (r = -0.59) and FM (r = -0.60), P<0.05. V_{200} was also negatively related to %F and FM, (r = -0.39 and r = -0.37, respectively, P<0.1). No relationships were found between body composition and gait characteristics.**

Conclusions: **Body composition was closely related to indirect measurements of aerobic capacity, which is a major factor of athletic performance in middle distance running horses.**

Potential relevance: **As in human athletes, trainers should take special note to evaluate optimal body weight and body composition of race horses to optimise performance.**

Introduction

In human athletes, relationships between body composition and physical performance have been widely studied. Many authors have reported positive correlations between lean mass and athletic capacity and, inversely, negative correlations between fat mass or percentage of fat and performance in different sports, such as long distance running (Hetland *et al*. 1998), modern penthatlon (Claessens *et al*. 1994), rowing (Cosgrove *et al*. 1999), swimming (Siders *et al*. 1993) or gymnastics (Feria and Feria 1989). Moreover, relationships between body composition and some physiological variables, such as velocity of lactate threshold have been studied (Buresh *et al*. 2004). These authors found significant negative correlations between fat mass or percentage of fat and velocity of lactate threshold.

In horses, Westervelt *et al*. (1976) demonstrated the value of ultrasonic measurements for the prediction of total body fat and investigated the effect of exercise and level of diet intake on body composition. With the same method, the relationships between body condition score and body composition were described in mares (Henneke *et al*. 1983). Some relationships between athletic performance and body composition were also investigated in sprinting races, in endurance races and in middle distance running. From total carcass dissections, Gunn (1987) compared body composition of Thoroughbreds with other types of horses to explain their superior sprinting ability. In endurance horses, the influence of bodyweight and condition score on performance were investigated (Garlinghouse and Burrill 1999). In Standardbreds, Kearns *et al*. (2002a) showed that fat free mass was related to race performance and that fat percentage was negatively correlated. Finally, these authors also showed that, in a population of unfit Standardbred mares exercised on a treadmill, $\dot{V}O_{2max}$ was related significantly to fat free mass (Kearns *et al*. 2002b). In trotters, some physiological and gait variables measured during a standardised exercise test on the track showed highly significant correlations with performance (Leleu *et al*. 2005a,b). The aim of the present experiment was to study the relationships between body composition in young Standardbreds and physiological and gait variables measured during a standardised exercise on the track.

Materials and methods

Horses

Twenty-four 2-year-old Standardbreds (16 males and 8 females) in training were studied. All horses were exercised using a traditional training schedule: 2 high-intensity training sessions/week (2 bouts of 5 mins at an average speed of 10 m/sec) completed by 2 low intensity training sessions (30–45 mins at mean speed 8.33 m/sec).

Height at withers and total body weight were measured. For each horse, a subjective body condition score was recorded using a scale 0–5, 0 being extremely emaciated and 5 extremely fat (Anon 1990).

Body composition evaluation

Rump fat thickness (RFT) was measured using an ultrasound scanner[1]. The site was determined by positioning the probe over the rump at 5 cm lateral from the midline at the centre of the pelvic bone (Westervelt *et al*. 1976). The region was scanned and the position of maximal fat thickness used as the measured site. Percentage fat (%F) was estimated from the equation:

%F = 2.47 + 5.47 x RFT (cm)

The coefficient of variation for the measurement of rump fat thickness was 2%. Fat mass (FM) was determined by multiplying %F by total body mass. Fat free mass (FFM) was derived by subtracting fat mass from total body mass.

Exercise test

Exercise tests were performed on the race track of Laval (1200 m sand track) under defined environmental conditions: dry track, temperature 10–20°C, little or no wind, to avoid any climatic influence. Each horse started with a 10 min warm-up at about 5.83 m/sec, and then a 3-step test at increasing speed (Demonceau and Auvinet 1992). The duration of each step was 3 mins, with a 1 min rest between 2 steps. The velocity of the 3 steps was 8.33, 9.16 and 10 m/sec.

Physiological measurements and data analysis

Trotting speeds, in m/sec, were measured and recorded using a tachometer SRM[2]. The driver used information on the screen to keep the speed as constant as possible during each step. The same device recorded heart rate during exercise. Following the test, data from tachometer and heartrate-meter were downloaded to a laptop computer to determine the mean speed and heart rate during each step. Jugular venous blood samples were collected within one min of the end of each exercise. The blood was collected into tubes containing fluoride oxalate for later determination of whole blood lactate concentration by the enzymatic method of Boehringer.

Two physiological variables were calculated for each horses from information on speed, heart rate and blood lactate concentrations at the 3 steps :

- V_4: velocity of a 4 mmol/l blood lactate concentration,
- V_{200}: velocity for a 200 beats/min heart rate.

Based on the value of V_4, three groups of horses were defined: Low V_4 group: horses with V_4<9.16 m/sec; Medium V_4 group: horses with V_4 9.16–9.66 m/sec; High V_4 group: horses with V_4>9.66 m/sec.

Gait measurements

The procedure for determination of gait variables used an accelerometric device (Equimetrix)[3] and was similar to those described by Leleu *et al*. (2004, 2005b). The variables measured were: Stride frequency (SF, stride/sec), Stride length (SL, m). Coefficients of variation were, respectively, 0.5% for SF and 2.2% for SL.

TABLE 1: Mean ± s.d. of morphological and physiological variables. n = 24

	Mean	s.d.	Min–Max
Body Weight: bwt (kg)	466	38	392–540
Height at withers: HW (cm)	163	4	157–172
Body condition score: BCS	3.1	0.7	2–4
% Fat	10.25	2.27	4.7–14.8
Fat Mass: FM (kg)	48	11	20–75
Fat Free Mass: FFM (kg)	418	35	342–491
V_4 (m/sec)	9.5	0.5	8.5–10.63
V_{200} (m/sec)	9.13	0.71	7.82–10.81

Statistical analysis

Mean ± s.d. of morphological, physiological and gait variables were calculated and studied using statistical software[4]. Analysis of variance and a Pearson's correlations matrix were calculated to study the relationships between body composition, body score, physiological and gait variables. Duncan's *post hoc* tests were applied if difference appeared. A level of significance of P<0.05 was used for all tests.

Results

Morphological and physiological data of the population

Table 1 shows mean ± s.d. of morphological and physiological variables in the population. Analysis of variance showed no significant difference in morphological and physiological variables between males and females.

Table 2 contains mean ± s.d. of gait variables on the 3 steps of the test.

Correlations between body composition and body condition score

Table 3 presents significant positive correlations between fat mass and % of fat and body condition score (r = 0.71 and r = 0.64, respectively, P<0.05).

Correlations between morphological and physiological variables

Table 3 shows significant correlations between morphological and physiological variables: V_4 was negatively correlated to %F and FM (r = -0.59 and r = -0.60, P<0.05). In addition, V_{200} was less negatively correlated to %F and FM (r = -0.39 and r = -0.37, P<0.05). FFM was not correlated to physiological variables.

On the basis of their value of V_4, 3 groups of 8 horses were defined (low, medium and high V_4). Figure 1 represents means ± s.d. of V_4 in the 3 V_4 groups. Means V_4 were significantly different in the 3 groups. Means of body weight were not significantly different between the 3 V_4 groups (Fig 2). The group with higher V_4 was significantly less fat than the 2 other groups (Fig 3).

Relationships between morphological and gait variables

No relationships were found between morphological and gait variables.

TABLE 2: Mean ± s.d. of gait variables

Step	1	2	3
Speed (m/sec)	8.46 ± 0.11	9.31 ± 0.13	10.11 ± 0.13
Stride frequency (stride/sec)	1.82 ± 0.09	1.87 ± 0.09	1.92 ± 0.07
Stride length (m)	4.68 ± 0.27	4.98 ± 0.26	5.26 ± 0.22

TABLE 3: Correlation matrix between morphological and physiological variables

	Bwt	%F	FM	FFM	BCS	V_4
%F	ns					
FM	0.44**	0.93**				
FFM	0.96**	ns	ns			
BCS	0.34*	0.64**	0.71**	ns		
V_4	ns	-0.59**	-0.6**	ns	-0.44**	
V_{200}	ns	-0.39*	-0.37*	ns	-0.45**	0.56**

**P<0.05; *P<0.1

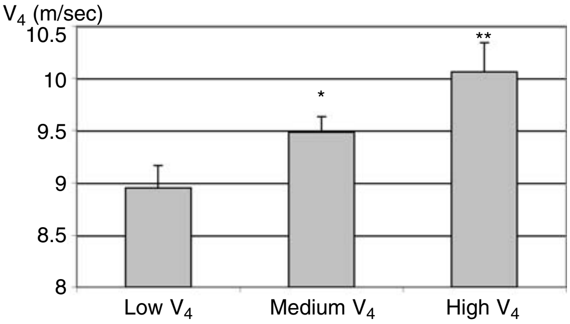

*Fig 1: Mean V_4 in the low, medium and high V_4 groups. *, ** Significantly different from one another.*

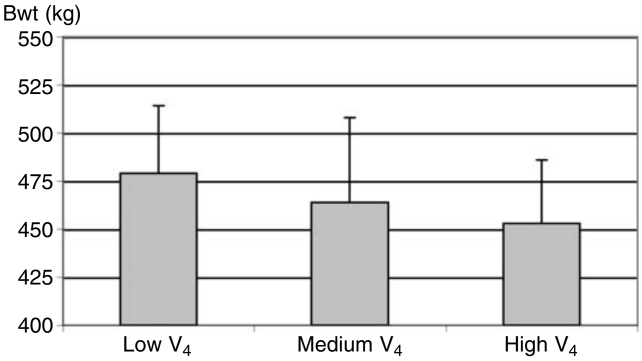

Fig 2: Means bodyweight with the low, medium and high V_4 groups.

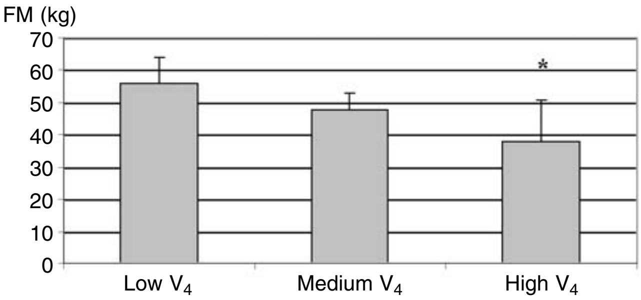

*Fig 3: Mean ± s.d. fat mass (FM) with the low, medium and high V_4 groups. * Significantly different.*

Discussion

Body composition and physiological data

Several studies have reported body composition of horses either from total carcass dissection or with ultrasound method. From dissections, Webb and Weaver (1979) described weight of tissues and organs of a population of 17 horses and ponies. They found mean ± s.d. body weight 291 ± 101 kg, weight of adipose tissue 17.7 ± 16.6 kg and muscle weight 132 ± 47 kg. They also calculated a % fat of 5.06% bwt which is low compared to our data (10.2 ± 2.3%), but 12 of 17 horses were described as lean or emaciated. These authors showed that the most variable component of bodyweight was adipose tissue with range <1% to >11%.

With ultrasonic evaluation, Kearns *et al*. (2002a) described body composition of 14 Standardbred horses age 3–4 years and in full physical condition. These authors found, in the population of males, mean bwt, mean fat mass and mean % fat, respectively, 432 ± 11 kg, 32 ± 4 kg and 7.4 ± 0.9%. In females, these data were 444 ± 13 kg, 44 ± 3 kg and 9.9 ± 0.5%. The horses, in our study, are a little more fat (% fat = 10.2 ± 2.3). One explanation concerns the duration of training. Our 2-year-old horses had been trained during a maximal period of 6 months whereas elite horses in the study of Kearns (age 3–4 years) had been trained for one or 2 years.

In population of 23 unfit Standardbred mares, Kearns *et al*. (2002b) described mean bwt, mean fat mass and mean % fat of, respectively, 514 ± 12 kg, 116 ± 8 kg and 22.3 ± 1.1%.

Interestingly, these values of % fat for athletic and non athletic population of horses are quite similar to those found in athletic and non athletic human population (Kearns *et al*. 2002c).

Concerning physiological data observed in the current study, the means V_4 and V_{200} are very similar to those found in other populations of 2-year-olds tested on the track with the same procedure (Couroucé *et al*. 2002). Gait variables were also similar to data described previously (Leleu *et al*. 2004).

Correlation between body condition score and body composition

Correlation between body condition score (BCS) and body composition estimated by ultrasound have been reported by Henneke *et al*. (1983) in a population of 20 Quarterhorse mares of varying body condition. The body score varied 1–9, one being extremely emaciated and 9 extremely fat. Positive correlations between BCS and bodyweight and between BCS and % of fat were significant: respectively r = 0.50 ($P<0.01$) and r = 0.65 ($P<0.001$). Those data were close to those found in our study: r = 0.34 ($P<0.1$) and r = 0.64 ($P<0.05$). In both studies, the condition score was positively related to % fat, and therefore a useful tool in managing body composition.

Correlation between body composition and physiological variables

In horses, very few papers have been published to relate physiological data during exercise and body composition. Kearns *et al*. (2002b), in a population of unfit horses, showed relationships between body composition, blood volume and maximal oxygen uptake. These authors concluded that rump fat thickess, i.e. % fat, and exercise packed cell volume are both independent of body mass and predictive of $\dot{V}O_{2max}$.

In man, Buresh *et al*. (2004) explored the relationships between velocity of lactate threshold (vLT) and body composition. In a population of 21 male runners, the authors found negative correlations between body mass and vLT (r = -0.76, $P<0.01$), fat mass and vLT (r = -0.70, $P<0.01$), between % fat and vLT (r = -0.59, $P<0.01$) and lean mass and vLT (r= -0.41, $P<0.05$). Velocity of lactate threshold was significantly related inversely to body mass and particularly fat mass. In our study, we found almost the same negative correlations between V_4 and fat mass and between V_4 and % fat (r = -0.6, $P<0.05$ and r = -0.59, $P<0.05$, respectively). Conversely, we did not find any correlations between V_4 and bodyweight or fat free mass.

The major finding from the present study was that a low fat mass makes a great contribution to high V_4, which is an indirect measurement of aerobic capacity and which is closely related to the level of performance in Standardbreds (Leleu *et al*. 2005a). In a review article, Kearns (2002c) gave the most likely explanation: the inverse relationship was related to the relative energy expenditure required to perform submaximal or maximal exercise. Fat is a non working tissue and a low fat mass improve the power-to-weight ratio. For example, in the present study, the least fat horse (428 kg bwt with 4.7% of fat) carried 20.2 kg of adipose tissue whereas the fattest horse had 74.8 kg of fat tissue to bear (506 kg bwt with 14.8% fat). This handicap of 55 kg may be a far from negligible weight during a race.

Correlations between body composition and gait variables

It has been reported that carrying a load of 10% body weight during horizontal treadmill trotting induced gait modifications

(Thornton *et al.* 1987). These authors showed a significant increase of stride frequency associated to a significant decrease of stride length when 5 horses were loaded with a weight of approximatively 45 kg. In the current study, the hypothesis that extra-weight would modify gait characteristics was not verified.

Body composition and performance

As expected, if body weight and composition influence physiological variables during exercise, performance can be altered correspondingly. In human athletes, Gualdi Russo *et al.* (1992) studied transversally the body composition of 1815 young sports participants of different sports and level of performance. One of their conclusions was that 'high aptitude' subjects showed higher fat free mass than 'middle aptitude' group, and also a lower fat percentage. The same conclusion was found by Hetland *et al.* (1998) in long distance runners, by Claessens *et al.* (1994) in penthalton.

In horses, Kearns *et al.* (2002a) found a significant positive correlation between body fat and race time ($r = 0.70$, $P<0.05$) while fat free mass was negatively correlated to running performance ($r = 0.65$, $P<0.05$). In the current study, the detrimental effect of fat mass on aerobic capacity and therefore on performance was found, but no relation between fat free mass and physiological data. One explanation is that the amount of muscle is an important criteria during sprinting but not during submaximal work. Moreover, fat free mass (calculated by substricting fat mass from bodyweight) is not equivalent to skeletal muscle mass and this approximation might induce discrepancies. Other evaluation of muscle mass characteristics (muscle thickness) have been studied but were related to performance (Kearns *et al.* 2002a).

Conclusion

The results show that body composition in race horses is closely related to indirect measurements of aerobic capacity, which is a major factor of athletic performance in middle distance running horses. Excessive fat mass can decrease performance. Evaluation of fat mass with this ultrasound techniques presents the advantages of being noninvasive, easy and reliable. Longitudinal studies should be carried out to show, as in human athletes, the importance of individual 'optimal' body weight and body composition. Defined during a period of high performance, these data could be goals to maintain or reach after, for example, a period of rest. As both nutrition and training influence body weight and composition, precise knowledge of their interaction is needed. Follow-up of equine athletes could then be proposed to trainers to optimise nutritional and training programs.

Acknowledgements

The authors wish to express their gratitude for funds obtained from the Conseil Général de la Mayenne, the Communauté de Communes de Laval and the Conseil Régional des Pays de la Loire.

Manufacturers' addresses

[1]Aloka, Tokyo, Japan.
[2]Schoberer Rad Meßtechnik, Jülich, Germany.
[3]Centaure Metrix, Fontainebleau, France.
[4]NCSS, Kaysville, Utah, USA.

References

Anon (1990) *Alimentation des chevaux*. Ed: W. Martin-Rosset. INRA Editions, Paris. p 232.

Buresh, R.J., Berg, K.E. and Noble, J.M. (2004) Relationship between measures of body size and composition and velocity of lactate threshold. *J. Strength Cond. Res*. **18**, 504-7.

Carroll, C.L. and Huntington, P.J. (1988) Body condition and weight estimation of horses. *Equine vet. J*. **20**, 41-45.

Claessens, A.L., Hlatky, Lefevre, J. and Holdhaus, H. (1994) The role of anthropometric characteristics in modern pentathlon performance in female athletes. *J. sports Sci*. **12**, 391-401.

Cosgrove, M.J., Wilson, J., Watt, D. and Grant, S.F. (1999) The relationship between selected physiological variables of rowers and rowing performance as determined by a 2000 m ergometer test. *J. sports Sci*. **17**, 845-52.

Couroucé, A., Chrétien, M. and Valette J.P. (2002) Physiological variables measured under field conditions according to age and state of training in French Trotters. *Equine vet. J*. **34**, 91-97.

Demonceau, T. and Auvinet B. (1992) Test d'effort de terrain pour trotteurs à l'entraînement : réalisation pratique et premiers résultats. In: *Compte-rendu de la 18ème Journée d'Etude, CEREOPA*, pp 120-132.

Feria, I.E. and Feria, E.W. (1989) Relationship of the anthropometric and physical characteristics of male junior gymanasts to performance. *J. sports Med. Phys. Fitness* **29**, 369-78.

Garlinghouse, S.E. and Burrill, M.J. (1999) Relationship of body condition score to completion rate during 160 km endurance races. *Equine vet. J., Suppl*. **30**, 591-595.

Gualdi Russo, E., Gruppioni, G., Gueresi, P., Belcastro, M.G. and Marchesini, V. (1992) Skinfolds and body composition of sports paricipants. *J. sports Med. Phys. Fitness* **32**, 303-313.

Gunn, H.M. (1987) Muscle, bone and fat proportions and muscle distribution of thoroughbreds and other horses. In: *Equine Exercise Physiology 2*. Eds: J.R. Gillespie and N.E. Robinson, ICEEP Publications, Davis. pp 253-264.

Henneke, D.R, Potter, G.D., Kreider, J.L. and Yeates, B.F. (1983) Relationship between condition score , physical measurements and body fat percentage in mares. *Equine vet. J*. **15**, 371-372.

Hetland, M.L., Haarbo, J. and Christiansen, C. (1998) Regional body composition determined by dual-energy X-ray aborptiometry. Relation to training, sex hormones and serum lipids in males long-distance runners. *Scand. J. Med. Sci. Sports*, **8**, 102-8.

Kearns, C.F., McKeever, K.H., Kumagai, K. and Abe, T. (2002a) Fat-free mass is related to one-mile race performancein elite Standardbreds horses. *Vet. J*. **163**, 260-266.

Kearns, C.F., McKeever, K.H., John-Alder, H., Abe, T. and Brechue, W.F. (2002b) Relationship between body composition, blood volume and maximal oxygen uptake. *Equine vet. J., Suppl*., **34**, 485-490.

Kearns, C.F., McKeever, K.H. and Abe, T. (2002c) Overview of horse body composition and muscle architecture : implications for performance. *Vet. J*. **164**, 224-234.

Leleu, C., Cotrel, C. and Barrey, E. (2004) Age and training related changes in locomotion of trotter race horses. Equine and Comparative Exercise Physiology, **1**, 107-117.

Leleu, C., Cotrel, C. and Couroucé-Malblanc, A. (2005a) Relationships between physiological variables and race performance in French standarbred trotters. *Vet. Rec*. **156**, 339-342.

Leleu C., Cotrel C. and Barrey E. (2005b) Relationships between biomechanical characteristics and race performance in Standardbred trotters. *Liv. Prod. Sci*. **92**, 39-46.

Siders, W.A., Lukaski, H.C. and Bolonchuk, W.W. (1993) Relationships among swimming performance, body composition and somatype in competitive collegiate swimmers. *J. Sports Med. Phys. Fitness*. **33**, 166-71.

Thornton J., Pagan J. and Persson S. (1987) The oxygen cost of weight loading and inclined treadmill exercise in the horse. In: *Equine Exercise Physiology 2*, Eds: J.R. Gillepsie and N.E. Robinson, ICEEP, Davies. pp 206-215.

Webb, A.I. and Weaver, B.M.Q. (1979) Body composition of the horse. *Equine vet. J*. **11**, 39-47.

Westervelt, R.G., Stouffer, J.R., Hintz, H.F. and Schryver, H.F. (1976) Estimating fatness in horses and ponies. *J. anim. Sci*. **43**, 781-785.